TP3 ISI Parameter Selection Methodology

Contributions & Support:

John Ewen	JDSU
Lars Thon	Aeluros
Piers Dawe, David Cunningham	Agilent
Sudeep Bhoja, John Jaeger	Big Bear
Vivek Telang	Broadcom
Tom Lindsay	ClariPhy
Lew Aronson, Jim McVey	Finisar
Martin Lobel	Intel
Nick Weiner, Ben Willcocks	Phyworks
Petre Popescu	Quake
Abhijit Shanbhag	Scintera

Outline

- Background
- Simulation Parameters
- Motivation
- Methodology for ISI Parameter Selection
- Preliminary Results
- Summary

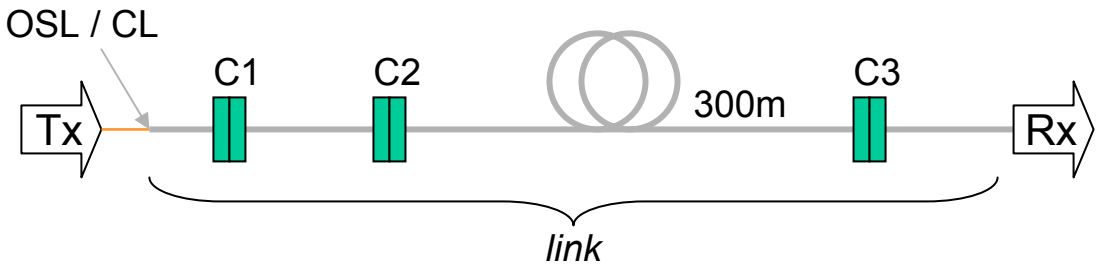
- Goals
  - Not a specific proposal or motion for new ISI parameters
  - Build consensus on methodology for ISI parameter selection
  - Target parameter selection at May Interim meeting

Background

- PIE-D alone seems an inadequate selection metric to define TP3 ISI parameters
  - Allows IPRs with unreasonably large or small implementation penalties
- LX4 & PSR screens are arbitrary metrics relative to LRM performance
- “Width” metrics do not correlate well with DFE performance
  - Screening on IPR time extent (+ PIE-D) will allow IPRs with unreasonably large or small implementation penalties
- Infinite FFE does not appear to correlate well with DFE implementation penalty.

- Finite DFE metric seems to be required
  - Yet want to avoid implementation specifics in standard definition

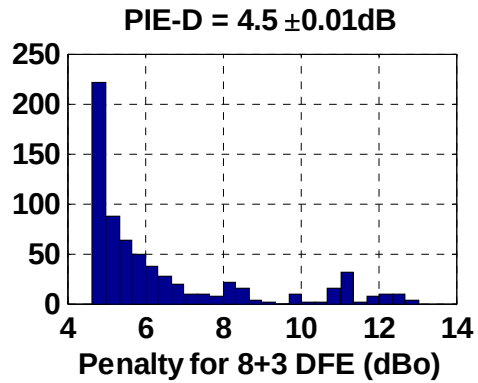
Simulation Parameters

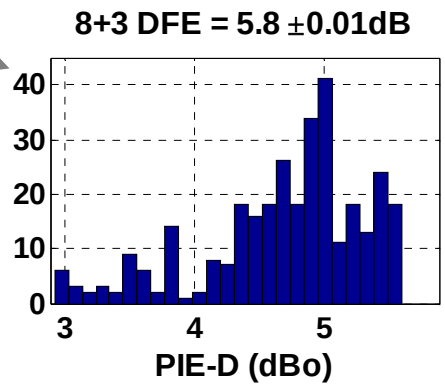


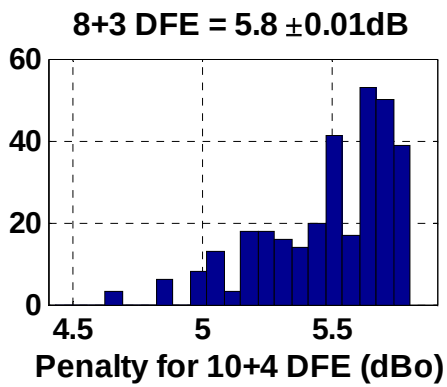
- Delay Set
  - Gen67YY
    - ≥ 500 MHz·km
    - 18 mode-groups
- Single-mode launch
  - center launch (CL): 0μm → 3μm
  - offset launch (OSL): 17μm → 23μm
  - best launch chosen for each pair
- Link Configuration
  - 1m – 1m – 300m – 1m
  - each fiber randomly chosen from delay set
- Connectors
  - 3 connectors
    - two prior to main fiber
    - one at end of main fiber
  - Random offset from Rayleigh distribution
    - mean = 3.58μm
    - truncated at 7μm
  - Total loss ≤ 1.5 dB
- Channel Metrics
  - 47.1 ps, 20%-80% Gaussian Tx filter
  - 7.5GHz, 4th-order BT Rx filter

Motivation

- Select PIE-D over very narrow window
  - Finite DFE penalty varies widely
- Select finite DFE penalty over very narrow window
  - PIE-D varies widely
  - Other finite DFE penalties vary widely







Issues

- Current selection method:
  - Run “many” Monte Carlo cases with variety of launches & connectors
  - Select resulting cases that are “close” to certain percentile of PIE-D
  - Sort cases into precursor, symmetric, and postcursor bins
  - Select each case with best fit to 4-tap FIR with 0.75UI spacing (PSR)
- Issues with current method
  - Will get wide ranges in penalties over finite ideal EQ
  - Imposing additional selection criteria (e.g. 8+3 DFE penalty) → null set
  - Running more Monte Carlo cases is not very productive
- Conclusions
  - Current approach yields too few candidate IPRs from MC67
    - none match given percentile “exactly” across a wide range of finite EQ
  - Widening the selection window yields too many candidate IPRs
    - not clear how to select among the resulting subset and whether the result is an adequate compliance test

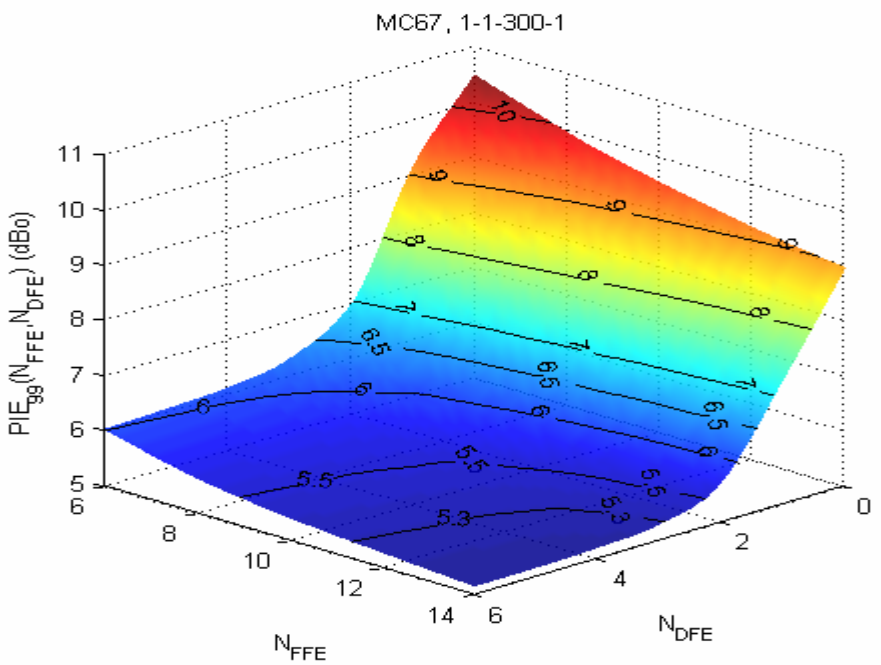
Proposed Selection Methodology

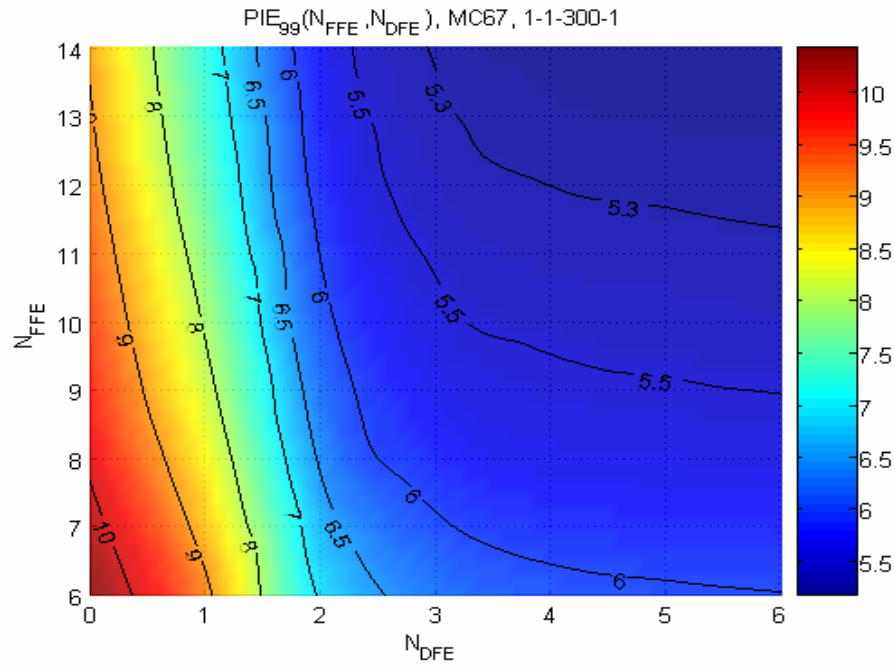
- Use MC67 to define the percentiles across a range of ideal finite DFE & PIE-D
  - A single finite DFE screen does not appear adequate
- Choose ISI parameters that match the *percentiles* of the total population, not a particular Monte Carlo case from MC67
  - Ensures TP3 test will screen poor implementations without being implementation specific

Definitions

- PIE = Penalty of *Ideal* Equalizer
  - PIE-D = infinite complexity DFE (nonlinear)
  - PIE-L = infinite complexity FFE (linear)
  - PIE(N,M) = finite complexity DFE (nonlinear)
    - N = # of T/2-spaced FFE taps
    - M = # of T-spaced DFE taps
    - PIE-D = PIE(∞,∞)
    - PIE-L = PIE(∞,0)
- $PIE_{xx}(N,M) \equiv xx^{th}$ percentile of PIE(N,M)
  - e.g. $PIE_{90}(\infty, \infty) = 90^{th}$ percentile of PIE-D
- $\Delta PIE_{xx}(N,M) \equiv PIE(N,M) - PIE_{xx}(N,M)$
  - $PIE_{xx}(N,M)$ is a property of the delay set & connector models
  - PIE(N,M) is a property of a *particular* pulse response

Percentiles vs. EQ Complexity





- Compute percentiles of a variety of finite DFE over the entire MC67 population
  - Vary # of T/2-spaced forward taps from 6 → 14
  - Vary # of T-spaced feedback taps from 0 → 6
  - Percentiles based on best of CL and OSL for each DFE structure

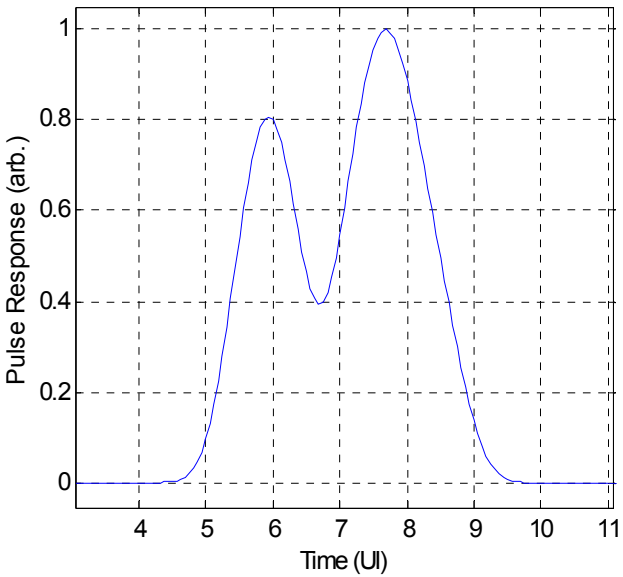
Proposed Selection Method

- Assume a 4-tap FIR stressor with uniform tap-spacing
  - Let the tap-weights and tap-spacing be variable
- Compute penalties relative to the percentiles of MC67, e.g.
  - $\Delta PIE_{xx}(N,M)$ for N=6, 8, …, 14; M=0, 1, 2, …, 6
  - $\Delta PIE_{xx}(\infty,\infty)$
- Adjust the set of tap-weights and tap-spacing, $\{A_i,\Delta t\}$, to minimize the mean-squared-error in the penalties relative to this percentile, i.e.

$$MSE = \min_{\{A_i,\Delta t\}} \left\{ \sum_N \sum_M w_{N,M} \left| \Delta PIE_{xx}(N,M) \right|^2 + w_\infty \left| \Delta PIE_{xx}(\infty,\infty) \right|^2 \right\}$$

  - With the constraints:
    - Sum of tap-weights = 1
    - tap-weights ≥ 0
    - w_i = error weighting function
- Validate resulting response against:
  - PIE(N,M), $\Delta PIE_{xx}(N,M)$, and %tile(N,M)

Precursor Example



Δt = 0.78 UI

A_i = { 0.38, 0, 0.39, 0.23}

PIE(N,M)		Ndfe 0	1	2	3	4	5	6
Nffe	6	10.27	9.40	6.56	5.85	5.84	5.84	5.84
	8	9.76	9.00	6.40	5.80	5.76	5.76	5.76
	10	8.96	8.25	6.32	5.57	5.57	5.57	5.57
	12	8.60	7.85	6.17	5.47	5.44	5.44	5.44
	14	7.89	7.53	5.93	5.33	5.33	5.33	5.33
	PIE-D	4.47						

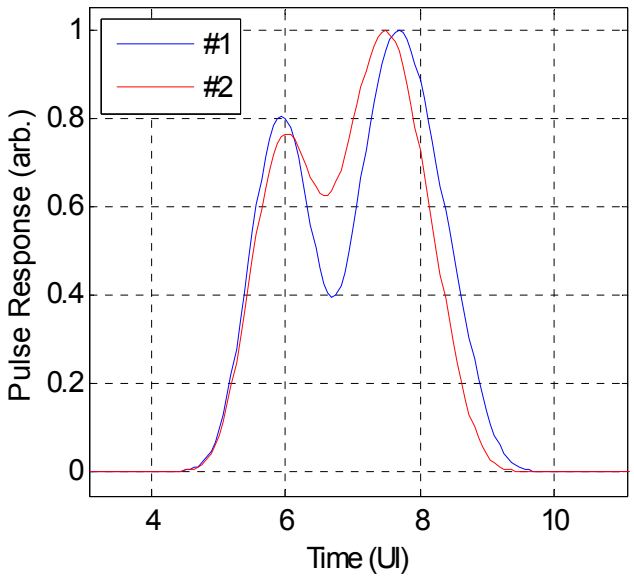
ΔPIE_{gg}(N,M)		Ndfe 0	1	2	3	4	5	6
Nffe	6	-0.19	0.31	-0.40	-0.42	-0.25	-0.20	-0.16
	8	-0.16	0.57	-0.04	-0.03	0.09	0.13	0.15
	10	-0.55	0.32	0.20	0.02	0.11	0.14	0.17
	12	-0.60	0.34	0.32	0.08	0.14	0.16	0.18
	14	-1.06	0.31	0.23	0.05	0.14	0.18	0.19
	PIE-D	-0.07						

%tile(N,M)		Ndfe 0	1	2	3	4	5	6
Nffe	6	98.7	99.3	98.3	98.1	98.4	98.5	98.6
	8	98.8	99.3	98.9	98.9	99.2	99.2	99.3
	10	98.3	99.2	99.2	99.0	99.2	99.3	99.3
	12	98.2	99.3	99.3	99.1	99.3	99.3	99.4
	14	97.4	99.3	99.3	99.1	99.3	99.4	99.4
	PIE-D	98.7						

PIE ≤ 6.5dB

- Matches PIE percentiles well
  - Slightly pessimistic except optimistic for low complexity EQ
  - Precursor-like response
- Consistent with previous work that ~0.75 UI and 4 taps can approximate a variety of fiber responses

Discussion



ΔPIE$_{99}$(N,M)	Ndfe 0	1	2	3	4	5	6
Nffe 6	-0.19	0.31	-0.40	-0.42	-0.25	-0.20	-0.16
8	-0.16	0.57	-0.04	-0.03	0.09	0.13	0.15
10	-0.55	0.32	0.20	0.02	0.11	0.14	0.17
12	-0.60	0.34	0.32	0.08	0.14	0.16	0.18
14	-1.06	0.31	0.23	0.05	0.14	0.18	0.19
PIE-D	-0.07						

#1: Δt = 0.78 UI

A_i = { 0.38, 0, 0.39, 0.23}

ΔPIE$_{99}$(N,M)	Ndfe 0	1	2	3	4	5	6
Nffe 6	-0.45	0.04	-0.52	-0.25	-0.06	0.00	0.03
8	-0.47	-0.38	-0.22	-0.05	0.11	0.14	0.16
10	-0.74	-0.13	-0.11	0.18	0.28	0.31	0.34
12	-0.84	0.12	0.04	0.05	0.15	0.17	0.18
14	-0.81	0.05	-0.12	0.03	0.13	0.16	0.17
PIE-D	0.19						

#2: Δt = 0.70 UI

A_i = { 0.34, 0.06, 0.37, 0.23}

PIE ≤ 6.5dB

- Different initial conditions give similar, but different solutions
  - Not an issue as long as solutions provide the correct stress to screen poor implementations.

Summary

- New TP3 ISI parameter selection process
  - Include finite DFE penalties along with PIE-D
  - Include a wide variety of finite DFE complexity
  - Choose the ISI parameters to provide the appropriate penalties relative to the Monte Carlo model
    - Match the penalties from the model, not a particular fiber response

- Future work
  - Agree on the link configuration, range of finite DFE, etc.
  - Evaluate the percentiles for the Monte Carlo model
  - Compute ISI parameters
  - Symmetric & postcursor responses
    - Are these needed?
    - How should they be chosen?